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36

Wildlife and Fire:
Impacts of Wildfire and Prescribed Fire on Wildlife and Habitats in Southwestern Coniferous Forests

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Intermountain West Frequent-Fire Forest Restoration

Ecological restoration is a practice that seeks to heal degraded ecosystems by reestablishing native species, structural characteristics, and ecological processes. The Society for Ecological Restoration International defines ecological restoration as "an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability….Restoration attempts to return an ecosystem to its historic trajectory" (Society for Ecological Restoration International Science and Policy Working Group 2004).

Most frequent-fire forests throughout the Intermountain West have been degraded during the last 150 years. Many of these forests are now dominated by unnaturally dense thickets of small trees, and lack their once diverse understory of grasses, sedges, and forbs. Forests in this condition are highly susceptible to damaging, stand-replacing fires and increased insect and disease epidemics. Restoration of these forests centers on reintroducing frequent, low-severity surface fires—often after thinning dense stands—and reestablishing productive understory plant communities.

The Ecological Restoration Institute at Northern Arizona University is a pioneer in researching, implementing, and monitoring ecological restoration of frequent-fire forests of the Intermountain West. By allowing natural processes, such as low-severity fire, to resume self-sustaining patterns, we hope to reestablish healthy forests that provide ecosystem services, wildlife habitat, and recreational opportunities.

The Southwest Fire Science Consortium (SWFSC) is a way for managers, scientists, and policy makers to interact and share science. SWFSC's goal is to see the best available science used to make management decisions and scientists working on the questions managers need answered. The SWFSC tries to bring together localized efforts to develop scientific information and to disseminate that to practitioners on the ground through an inclusive and open process.

ERI working papers are intended to deliver applicable science to land managers and practitioners in a concise, clear, non-technical format. These papers provide guidance on management decisions surrounding ecological restoration topics. This publication would not have been possible without funding from the USDA Forest Service and the Southwest Fire Science Consortium.

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Cover Photo: Abert's squirrels (*Sciurus aberti*), like this one climbing a ponderosa pine tree, depend on mature forests for nesting and cover. Abert's squirrels can be negatively affected by wildfire if high amounts of canopy cover and structural diversity are lost.

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Introduction

The southwestern United States has experienced over a century of fire suppression that has altered natural fire regimes and caused an increase in fuel loads and increased fire frequency, severity, intensity, and size of wildfires (Covington and Moore 1994, Moore et al. 1999, Swetnam et al. 2001). Long-term fire exclusion, livestock grazing, and management practices have resulted in more dense forest structure that is departed from its natural range of variability, and forests that once experienced frequent low intensity fires are now more susceptible to large scale, high intensity stand-replacing fires, drought, and insect attacks (Covington and Moore 1994, Moore et al. 1999, Allen et al. 2002, Schoennagel et al. 2004). Large intense wildfires can have substantial effects on native plants and animals and their habitats. Changes in vegetative structure and composition, cover type conversions, habitat fragmentation, and the creation of edge effects are some of the major impacts that large-scale fires can have on wildlife habitat.

The return of fire-driven processes to dry coniferous forests in the Southwest can aid in restoring ecological processes, create ecologically important early successional habitats, and it helps maintain biodiversity of wildlife habitats (Brawn et al. 2001). Fire is natural disturbance that plays an important role in creating a mosaic of habitats and successional stages that support a suite of native plants and wildlife within a landscape (Angelstam 1998). A mosaic of habitat types at the landscape scale increases the complexity of landscape structure and composition, and increases diversity on multiple levels by providing multiple seral stages that many animals can use throughout their life cycle. Historical fire exclusion along with other management activities has reduced landscape-scale heterogeneity by reducing the amount of fire-generated early successional forests and the complexity of habitats that were historically maintained by frequent low-severity fire (Noss et al. 2006a). Restoring and facilitating natural fire regimes can meet both restoration and conservation objectives, and return functional processes to our forests while reducing the risk of large catastrophic wildfires that impact wildlife species.

Understanding how fire severity, extent, seasonality, spatial complexity, and post-fire forest conditions influence species response is important for predicting the effects of wildfire and management actions on wildlife. Site specific factors, disturbance history, and fire severity are important elements in understanding species abundance and distribution after fire events. This paper focuses on the use and effects of wildfire (natural ignition), prescribed fire (purposeful ignition), and restoration treatments (thinning and prescribed fire) on terrestrial fauna in dry coniferous forests primarily in the southwestern U.S.

Direct and Indirect Effects of Fire on Wildlife

Impacts of fire on wildlife can be both direct and indirect. Direct effects include fatality, emigration out of burned areas, immigration into new areas, injury, increased predation from lack of cover, and decreased food availability. Most wildlife deaths occur due to smoke inhalation, suffocation, burns, or immobility (Lyon et al. 2000). Highly mobile animals (e.g. ungulates, birds) are capable of escaping fire and moving in to unburned refugia. Less mobile species (e.g. reptiles and frogs) can survive in burrows, crevices, and underground refugia. Fossorial animals such as some small mammals can survive fires if their subterranean tunnel systems are extensive and can protect them against heat intensity (Lyon et al. 2000). Spring wildfires can impact breeding, nesting, denning, burrows, or cavities or make individuals more susceptible to predation by reducing the amount of canopy or understory cover (Ward 1968).

Indirect effects of fire on wildlife include changes in vegetative structure, diversity, species composition, and other components of their habitat. Fire burns heterogeneously across a landscape leaving a matrix of burned and unburned areas of varying fire severity in a patchy arrangement. Fire influences patch size, shape, connectivity, and juxtaposition (Shaffer and Laudenslayer 2006) and the spatial arrangement of habitat at multiple scales, from the stand to the landscape level. The resulting mosaic of burned and unburned patches is key in maintaining diversity and spatial heterogeneity that is important to multiple species of wildlife that use an array of seral stages and habitat types both seasonally and for life history needs. In forests and woodlands, understory fires generally alter habitat structure less than mixed-severity and stand-replacement fires, and their effects on animal populations using existing habitat are less severe. In the short term, patches of low-severity, lightly burned areas can provide refuge for wildlife; whereas high-severity burns can kill trees, thereby limiting cover and available resources (Smith et al. 2000). New structural and habitat features are created post-fire, including stands with both live trees and some snags or stands with nearly 100 percent snags, and these variations in post-fire structure translate into variations in wildlife species' response to fire (Smucker et al. 2005). Standing dead and dying trees and downed logs are important structures to wildlife, particularly used for foraging, nesting, and roosting habitats (Saab et al. 2007). An increase in these dead and decaying trees may also increase bark and wood-boring beetle abundance, a primary food source for many woodpeckers and other insectivores. Plant regrowth post-fire can lead to an increase in vegetative sprouts, flowers, and seeds, thus increasing forage (Saab et al. 2007). Alternatively, high-severity wildfire can promote invasion by exotic plant species because many exotics respond to disturbance, space, and nutrients available post-fire and in turn can increase fuel loads, change fire regimes, and degrade available wildlife habitat and forage.

Measuring Species Response

The effects of fire on wildlife species response are widely measured using changes in species abundance, distribution, and density, but vary across the body of literature. The best comparative studies allow measuring wildlife presence/absence, abundance, and stand conditions pre and post-fire, however many studies take advantage of large-scale wildfires that have occurred, thereby limiting the inference to one landscape and one point in time with no pre-fire stand or population information. Characteristics of the individual fire, site specific variability, burn severity, heterogeneity, pre and post-fire vegetation structure and composition, fluctuations in species populations, abiotic conditions, and time since fire should be taken in to account when making inferences on species responses.

Fire Regimes and Fire Severity

Fire regimes impact forest structure, composition, and overall heterogeneity. Coniferous forests in the southwestern U.S. were historically characterized by frequent (every 0–35 years) low-severity fires in ponderosa pine (*Pinus ponderosa*) and recurrent low to moderate severity fires with variable fire return intervals in dry mixed conifer forests (Fulé et al. 2003, Reynolds et al. 2013). Animal communities have evolved with particular fire regimes and exhibit patterns of response to the vegetation changes that occur post-fire. The ability for wildlife species to persist post-wildfire depends on food availability, cover, mobility, behavior, and structural diversity. Fire return interval, severity, intensity, extent, and scale are important determinants of species habitat and therefore species abundance and distribution after a fire event.

Fire severity is used to describe the loss or decomposition of organic matter, both aboveground and belowground, and describes the degree to which vegetation and soil have been modified by the fire (Keeley 2009). Different fire severities produce different post-fire structures in terms of standing and dead vegetation at both the stand and landscape scale, and successional stage of the forest post-fire should be considered when making inferences on changes in species response. Incorporating fire severity is important to understanding individual species response to post-fire conditions, as each species has distinct habitat requirements and will respond differently to varying levels of fire severity that result in a mosaic of forest structures. Responses are also related to uniformity and intensity (heat energy released) of the fire, and availability of food and cover post-fire (Smith et al. 2000).

Fire severity is not consistently defined in terms of the loss of the dominant vegetation across the body of literature. Most studies report burn severity as low, moderate, or high percent loss, however vagueness exists in the actual quantification of these descriptors (Kennedy and Fontaine 2009). This is especially problematic when describing a mixed-severity fire where a mosaic of burn severities exists across the landscape. Fire burns heterogeneously across a landscape leaving a mosaic of unburned and burned patches at various severities, thus patch size, shape, and severity can all influence wildlife distributions in a burned landscape. In general, low-severity, low-intensity fires burn on or above the forest floor; moderate severity, moderate-intensity fires are those that kill a portion but not all of the forest overstory; and high-severity, high-intensity fires are those that result in complete or nearly complete mortality of the overstory. Other definitions focus more on soil effects than on vegetation. Metrics should describe vegetation mortality and structural and compositional changes such as percent loss of dominant and overstory vegetation, basal area loss, bole char, and canopy loss. Carefully defining these metrics can help elucidate the mechanisms behind the animal response.

Species Response to Wildfire: Examples in Dry Coniferous Forests

Avifauna

Birds are a well-studied taxon with regards to response to the effects of wildfire. Several species have evolved with fire (e.g. Kirtland's warbler, American three-toed woodpecker) and have adapted to exploit the resources that occur post-fire. Many woodpeckers inhabit burned areas immediately post-fire, followed by a decrease 2–4 years later (Covert-Bratland et al. 2006, Saab et al. 2007). For example, hairy woodpeckers (*Picoides villosus*) and American three-toed woodpeckers (*Picoides dorsalis*) are found in high-severity burned areas due to increased seed production and insect infestations post-fire and use moderate and high-severity patches during winter (Covert-Bratland et al. 2006, Kotliar et al. 2008). Black-backed woodpeckers (*Picoides arcticus*) favor high-severity burned areas and immigrate to these areas to exploit trees infested with insects and the abundance of newly created snags and cavities (Lyon et al. 2000). There are several species that respond positively and increase in abundance and/or densities post-fire, including Townsend's solitaire (*Myadestes townsendi*), dark-eyed junco (*Junco hyemalis*), lazuli bunting (*Passerina amoena*), Cassin's finch *(Carpodacus cassinii*), house wren (*Troglodytes aedon*), western wood pewee (*Contopus sordidulus*), and Western bluebirds (*Sialia Mexicana*), among others (Smucker et al. 2005, Kotliar et al. 2007). Other species such as the eastern meadowlarks (*Sturnella magna*) and Cassin's sparrows (*Aimophila cassinii*) avoid burned areas 2–3 years post fire due to lack of shrub cover and grass cover (Bock and Bock 1992).

Many insectivores rapidly colonize burned areas and then experience a decrease in density as time since fire increases, likely due to declines in bark and wood-boring

Box 1: Northern Goshawks and Fire

The northern goshawk (*Accipiter gentilis*) evolved in forests structured by fire. Goshawks occupy a variety of forest types with structural diversity, and use mature canopy forests with open understories for foraging and roosting (Reynolds et al. 2006). Their ability to hunt in the sub-canopy forest space is impaired when forest understories become dense with small trees and brush (Reynolds and Meslow 1984). In southwestern coniferous forests, the absence of frequent surface fire creates patches and clumps of dense saplings that can inhibit goshawk detection and access of ground prey, such as squirrels, rabbits, grouse, and other birds and small mammals (Reynolds et al. 1992). Frequent low-severity surface fires can help maintain hunting and roosting habitats across their southwestern range and increase the productivity of habitat used by some of their main bird and mammal prey species on the Kaibab Plateau.

Northern goshawk (*Accipiter gentilis*). *Photo courtesy of the Arizona Game and Fish Department*

beetles (Hoyt and Hannon 2002). In contrast, Lewis's woodpecker (*Melanerpes lewis*), an aerial insectivore, is abundant in both recent burns (2–4 years post-fire) and older burns (10–25 years post-fire; Bock and Lynch 1970, Saab and Vierling 2001). Other aerial insectivores and open-space foragers (e.g. western bluebirds (*Sialia mexicana*), mountain bluebirds (*Salia currucoides*), flycatchers (*Empidonax spp.),* and swallows (*Tachycineta spp.)* often use burned forests 10–20 years after fires in response to open conditions for aerial foraging following decreases in canopy cover and increases in insects associated with shrub regrowth (Lowe et al. 1978, Hobson and Schieck 1999, Hannon and Drapeau 2005).

Avian responses to wildfire are a function of patch size, patch shape, burn severity, and post-fire structure on the landscape (Smucker et al. 2005, Kotliar et al. 2008). Some species show a strong decline in density with increasing burn severity (e.g. mountain chickadee (*Poecile gambeli*), warbling vireo (*Vireo gilvus*), dark eyed junco), some species exhibited a neutral response with no change in densities (e.g. white breasted nuthatch (*Sitta carolinensis*), Virginia's warbler [*Oreothlypis virgiiae*]), while others exhibit a positive density response with increasing burn severity (e.g. western bluebird, broad tailed hummingbird (*Selasphorus platycerus*), house wren, western wood pewee) (Kotliar et al. 2007). Many species respond to an increase in resources immediately following a fire, then declining 2–4 years post-fire (Smucker et al. 2005, Kotliar et al. 2007, Saab et al. 2007). There is spatial and temporal variability in avian responses to wildfire, and understanding changes in abundance and density in relation to fire severity, post-fire structure and composition, and time since fire have important implications for species response.

Small Mammals

Small mammals are widely distributed, have rapid population growth, and have immediate responses to disturbance. Availability of food and cover are important factors influencing small mammal abundance after fire and they influence species differently (Fa and Sanchez-Cordero 1993, Roberts et al. 2008). In the short term, patches of low-severity burn areas can provide refuge for small mammals, whereas severe high intensity burns can kill both the understory and trees thereby limiting cover and resources (Smith et al. 2000). Fire can increase the availability of coarse woody debris (stumps and logs) for hiding, nesting, and living space (Lowe et al. 1978), as well as increase the abundance of insects, seeds, and annual forbs and grasses, which are important food sources for small mammals (Floyd-Hanna and Romme 1972, Lowe et al. 1978).

Small mammal response to wildfire is variable throughout forest successional stages post-fire. Initially 0–10 years post disturbance the abundance of small mammals can increase with the age of the stand, in accordance with species-specific habitat associations (Lee 2002, Fisher and Wilkins 2005). Shifts in relative abundance and evenness will occur within the small mammal community rather than complete species turnover. For example, in southern Arizona brush mice (*Peromyscus boylii*) had higher abundance in unburned areas than burned areas, while cactus mice (*Peromyscus eremicus*), a species most often associated with rocky, dry, and open areas, were only found in newly burned areas (2–3 years post fire) (Monroe et al. 2004). In recent low to moderate-severity burned areas the recently opened understory and canopy can increase the amount of food and cover to allow species to immigrate into a previously unused area. Pinyon mice (*Peromyscus truei*), a habitat specialist, were consistently more abundant in unburned areas and declined by 69–76 percent in moderate and high-severity burned areas, whereas a generalist species the North American deermice (*Peromyscus maniculatus*) increased 72–87 percent in burned areas (Borchert et al. 2014). Generalist species such as North American deermice often initially colonize an area post-fire, and recent burns may be dispersal sinks for juveniles (Fisher and Wilkinson 2005). Southern red-backed voles (*Myodes gapperi*), often considered old-growth or mature forest specialists, initially decline in burned areas, however they repopulate burns within three years following wildfire (Krefting and Ahlgren 1974). Other species, such as white throated woodrats (*Neotoma albigula*) had difficulty recolonizing burned areas likely because their middens were destroyed by fire, and were found to use unburned areas more than burned areas post-fire (Monroe et al. 2004). Burn severity, scale, site characteristics, successional stage and surrounding habitat also influence small mammal distribution, abundance, and density in burned areas (Roberts et al. 2008).

Red squirrels (*Tamias hudsonicus*), Abert's squirrels (*Sciurus aberti*), and other tree squirrels depend on mature forest stands for nesting, caching, and cover (Steele and Koprowski 2001). Squirrels are temporarily adversely affected by fire if nests, cavities, and food resources are reduced (Koprowski et al. 2005). Abert's squirrels can be negatively affected by wildfire if high amounts of canopy cover and structural diversity are lost. Endangered Mount Graham red squirrels (*Tamius hudsonicus grahamensis*) in southern Arizona selected unburned sites for midden locations, however the size of individual home ranges in a low-intensity burned area decreased over time, indicating high availability of resources in a low-severity burned area (Blount and Koprowski 2012). Burn severity influences use of middens and nests, and can create edge effects and habitat fragmentation that can negatively affect species abundance and occupancy.

Research shows that pinyon mice (*P. truei*) are habitat specialists that are more abundant in unburned areas. Their numbers declined by 69–76 percent in moderate and high-severity burned areas.

Herbivores, such as elk *(Cervus elaphus canadensis)*, can be impacted by wildfire in the short term. But wildfires can open dense canopies and allow an increase in understory plants that elk feed on. *Photo by Michael Quinn, courtesy of Grand Canyon National Park*

Herbivores and Carnivores

Herbivores, primarily elk, deer, and bighorn sheep, are mainly impacted by wildfire over the short term due to loss of forage, understory vegetation, and changes in vegetation structure and composition. Wildfires can open dense canopies, allowing understory plants to increase in density, open up movement pathways, increase visibility and the ability to avoid predators (Krausman et al. 2001). In the San Francisco Peaks in northern Arizona, elk (*Cervus elaphus canadensis*) selectively browsed in stands that experienced high-severity burns and consequent re-sprout of aspens (Bailey and Whittam 2002). Elk have been shown to browse in high-severity burned areas up to three years post-fire. Desert bighorn sheep (*Ovis canadensis Mexicana*) used recently burned areas when dense canopies were opened (Cain et al. 2005).

There is scant published literature discussing how carnivores, mesocarnivores, and other large mammals respond to wildfire or restoration treatments. Carnivore response to wildfire can include changes in recruitment, demographics, abundance, and home range size (Cunningham and Ballard 2004). In Arizona, female black bears (*Ursus americanus*) used unburned patches 90 percent of the time (Cunningham et al. 2002), and females with cubs sought out cover and food resources in unburned patches. Male black bears primarily used burned areas and increased their home range post-fire. In central Arizona canids such as coyotes (*Canis latrans*) use both burned and unburned areas, whereas gray foxes (*Urocyon cinereoargenteus*) use unburned areas more frequently than burned. This was likely due to a short-term reduction of cover and food availability post-fire, highlighting the importance of shrub and vegetation diversity for gray fox (Cunningham et al. 2006).

Box 2: Conserving the Jemez Mountains Salamander

The Jemez Mountains salamander (*Plethodon neomexicanus*) is a small terrestrial amphibian that spends most of its time underground in moist soils. More than 90 percent of the population resides within the Santa Fe National Forest in New Mexico and it is a federally endangered species. The range of Jemez Mountains salamander (JMS) is limited to the higher elevations (7,200–8,500 ft) of the Jemez Mountains and persists in highly fragmented populations of suitable habitat in coniferous forests and uses decayed logs and coarse woody debris to forage and burrow (Degenhardt et al. 1996, Petranka 1998). The JMS population has declined due to increased wildfire intensities, drought, climate change, and habitat fragmentation.


The Jemez Mountains salamander. *Photo by Todd Pierson*

High-severity wildfire that destroys canopy cover and removes ground cover is detrimental to JMS because they need cool, moist conditions for refuge and foraging. Large-scale stand replacing wildfires destroys JMS habitat, and over the last 20 years high severity fires in JMS habitat have negatively affected populations. The Dome Fire (1996) and Cerro Grande Fire (2000) destroyed one-third of JMS habitat in moderate to high severity patches. The Los Conchas fire (2012) burned JMS occupied stands and essential habitat, and burned 18,000 acres of essential habitat at high severity. Post-fire salvage logging removes JMS habitat, disturbs substrates, and can increase the rate of soil desiccation, all factors detrimental to JMS.

JMS likely evolved with frequent low-intensity surface fires and small patchy crown fires. Restoring conifer forests in the Jemez Mountains to a fire regime that more closely matches the historic range of variability that the JMS evolved with, and implementing fuel reduction and prescribed fire will likely allow for continued persistence of JMS habitat. Protecting large downed logs and using spring prescribed low intensity surface fires is recommended.

Herpetofauna

Herpetofauna (reptiles and amphibians) are mainly impacted by wildfire due to changes in soil properties, vegetation structure and composition, and removal of understory (Russell et al. 1999). Many reptiles and amphibians seek cover underground or in the burrows of other species (e.g. tortoises, small mammals) to avoid surface fires and can survive low to moderate-severity wildfire if the soil temperatures stay below a critical threshold. Amphibians such as toads and frogs have limited movement and poor dispersal capabilities (Sinsch 1990). Additionally, the moist and permeable skin and eggs of amphibians increases their vulnerability to heat and microhabitat drying (Stebbins and Cohen 1995). Many species respond positively to post-fire conditions that include increased insects and food availability (Cunningham et al. 2002).

Fire in a Forest Restoration Context

Re-introducing fire to our ecosystem has been a primary objective and a preferred restoration approach in the southwestern U.S. Restoration treatments such as prescribed fire, thinning, thinning plus prescribed fire, and managed wildfire are a means of reducing fuel accumulation and the risk of large-scale, high-severity wildfire. Restoration treatments are also a means to restore functional patterns and processes in southwestern forests. These treatments can return forest structure and composition to conditions within the natural range of variability and set landscapes on a trajectory toward ecological health and integrity. The importance of reintroducing fire (prescribed fire and managed wildfire) as a disturbance agent to represent the ecological effects of a natural fire regime, particularly in creating a mosaic of patches, can be an effective tool in maintaining biodiversity and ecosystem function.

Prescribed fire and thinning can be used to maintain complex landscapes with heterogeneous patch mosaics with multiple successional stages that are important to many species of wildlife. It is important to define the desired conditions on a landscape and which species would be present or absent under those specified conditions (Youngblood et al. 2007), and strive to emulate the natural range of variability in conditions for that particular landscape. The response of wildlife to prescribed fire and thinning varies by species and treatment type (Kotliar 2007). In the short term, a variety of restoration treatments in a patchy arrangement both spatially and temporally across the landscape is likely to result in the highest species and habitat diversity compared to any one treatment (Noss et al. 2006a).

Most active restoration studies are dominated by birds and small mammals. Meta-analyses of thinning and prescribed burning treatments across the western U.S. found that many species of small mammals and birds responded positively in terms of abundance and density to treatments with thinning plus low/moderate severity fire (Kalies et al. 2010, Fontaine and Kennedy 2012). Some species responded similarly to low/moderate-severity prescribed fire and forest thinning treatments used as a fire surrogate, suggesting that at the stand scale and in the short term (0–4 years), thinning may adequately mimic low/moderate-severity fire in terms of its effects on vertebrates (Fontaine and Kennedy 2012). Species preferring open conditions (e.g. western bluebird, chipping sparrow [*Spizella passerine*]) and disturbance (e.g. hairy woodpecker) responded positively to thinning treatments, whereas species preferring closed canopy conditions (e.g. hermit thrush [*Catharus guttatus*]) had a negative response. Treatments that included thinning plus low/moderate severity fire provided a higher level of positive species responses (e.g. golden mantled ground squirrel [*Spermophilus lateralis*]) compared to low-severity fire alone (Fontaine and Kennedy 2012). Some species of small mammals (e.g. North American deermice [*Peromyscus maniculatus*]) respond similarly to both thinning and prescribed fire, suggesting that vegetative structure plays an important role in the post-fire responses of some wildlife species (Converse et al. 2006a, Kennedy and Fontaine 2009).

In southwestern coniferous forests, species generally have positive density responses to restoration and fuels treatments including small-diameter tree removal, low/moderate severity prescribed burning, and thinning and burning combined, and negative responses 0–10 years after treatment to high-severity fire that removed overstory (Kalies et al. 2010, Fontaine and Kennedy 2012). Most ground-dwelling rodents responded positively to thinning (e.g. gray-collared chipmunk (*Tamias cinereicollis*), Mexican woodrat (*Neotoma Mexicana*), least chipmunks (*Tamius minimus*), and North American deermice) and thin/burn treatments (e.g. goldenmantled ground squirrel (*Spermophilus lateralis*) and gray-collared chipmunk). North American deermice densities increased in both treatments and in response to wildfire (Kalies et al. 2010, Converse et al. 2006c). However, some arboreal species such as Abert's squirrels responded negatively to both thinning and burning that removed overstory and canopy cover. Total small mammal biomass generally increased following both thinning and wildfire (Converse et al. 2006b). Individual species and taxa have individualistic and variable responses to restoration and fuels reduction treatment types in different areas, however total small mammal biomass generally increases after treatments (Converse et al. 2006c). Restoration and fuels treatments such as mechanical thinning can be an alternative to fire use in areas located near urban populations or in the wildland-urban interface (Kennedy and Fontaine 2009). When using thinning as a surrogate for fire it is important to note that vegetation regeneration, nutrient cycling, and fuel dynamics differ (Boerner et al. 2009) and should be considered when making inferences and expectations of vegetation and wildlife species response.

When species were grouped into foraging guilds to summarize differences between species response to treatment type, ground-foraging birds and rodents had consistently neutral density responses to the treatments, whereas aerial foraging species respond positively to small diameter tree removal and burning treatments, tree-foliage and bole-foraging birds responded neutrally or positively to small-diameter tree removal and burning treatments, but negative responses to overstory removal and high-severity or stand-replacing wildfire (Kalies et al 2010). Sites that contained fuel reduction treatments in southwestern ponderosa pine forests in Arizona had western bluebird densities increase on all treatments with densities more than doubling on the burn-only and thin and burn treatments, mountain chickadee (*Poecile gambeli*) densities decreased on all treatment types, pygmy nuthatch (*Sitta pygmaea*) densities remained constant across treatments except the thin-and-burn treatments where densities increased by 500 percent, and yellow-rumped warbler demonstrated a mixed response to treatments, with the largest change in density on the thin-and-burn treatment, decreasing by 100 percent (Hurteau et al. 2008).

Summary

Research suggests forests in the southwestern U.S. should be managed for a range of conditions that take into account the natural range of variability, past land use, a range of fire severities, and overall landscape heterogeneity that provides multiple seral stages including early seral, mid seral, and old growth habitats for multiple wildlife species (Fulé et al. 2004, Noss et al. 2006b, Kotliar et al. 2007, Kennedy and Fontaine 2009). The amount and distribution of these habitat types will vary within the ecosystem, and fire management that includes a broad range of variability and severity, including areas of severe fire, is more likely to preserve a broad range of wildlife habitat than restoration objectives based on narrowly defined historic fire regimes (Allen et al. 2002, Fulé et al. 2004, Schoennagel et al. 2004, Noss et al. 2006b, Kotliar et al. 2007, Kennedy and Fontaine 2009).

Fire has both positive and negative impacts on wildlife species depending upon the severity of the burn, spatial extent, post-fire structural and compositional elements, and the resulting habitat mosaic. Many species of wildlife inhabit forests that have evolved with structural conditions that depend on fire as a disturbance agent. Some species have evolved with fire and increase their abundance in burned areas whereas others have neutral or negative responses. The habitat mosaic is important, and fire can maintain ecosystem function and biodiversity. Early successional habitat created by fire is important to multiple species of wildlife and is limited in many forests across the western U.S. (Noss et al. 2006b). Overall, the impact of fire as a disturbance agent on wildlife habitat and consequently species abundance and density is ultimately species-specific, and there will always be some species that respond positively, some that respond negatively, and others that have neutral responses. Given that most landscapes support specialists that require either early seral or mature older forests, as well as species that require multiple seral stages throughout their life cycle, it is likely that a mosaic of successional stages is needed in the landscape to maximize biodiversity (Fontaine et al. 2009, Roberts et al. 2010).

Management Implications

- A fire's patch size, shape, and severity can influence wildlife distributions across a burned landscape and post-fire vegetation structure and composition are important in determining species response.
- Explicitly defining fire severity as a percent of basal area loss or more descriptive severity categories other than low, moderate, and high is needed in order to provide more informative insights in to species response.
- Low to moderate-severity fire can benefit multiple species of wildlife by altering understory conditions, while high-severity fire can immediately alter habitat structure and available resources.
- High-severity fire most negatively affects canopy-nesting and foliage foraging bird species, while many insectivores and cavity nesting birds increase due to the open conditions and snags created post-fire.
- Time since fire is important to species response. Often there is an increase in insects and seeds in the short term (0–4 years post-fire) that many species exploit, while others respond to overall structural characteristics over the long term.
- Many small mammal species respond positively to increased food sources post-fire such as forbs, grasses, seeds, and fungi. Squirrels are negatively affected when their middens or nests are destroyed and overstory is removed.
- Many avian species in the Southwest respond positively in terms of density and abundance to low and moderate-severity fire (e.g. western bluebird, hairy woodpecker, Steller's Jay, plumbeous vireo, dark-eyed junco).
- Many insectivores rapidly colonize burned areas and then experience a decrease in density as time since fire increases.
- In some areas, prescribed fire and/or thinning may be used to mimic the role of wildfire; however, at the landscape scale these effects are not well understood and need more research.

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